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ENVIRONMENTAL CONTROL ASPECTS OF IN SITU COAL GASIFICATION: GROUND-WATER QUALITY CHANGES AND SUBSIDENCE EFFECTS

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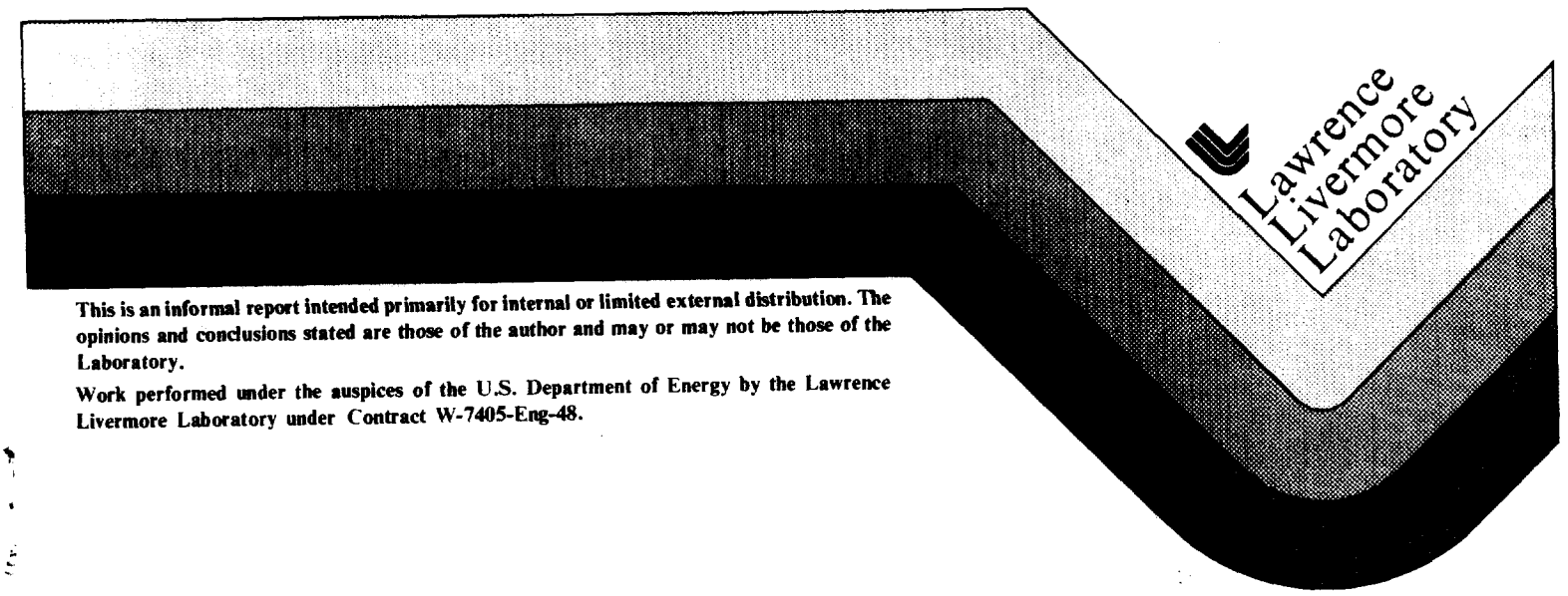

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ENVIRONMENTAL AND SAFETY ENGINEERING DIVISION
FY 1980 ANNUAL PROGRAM SUMMARY

PROJECT TITLE

ENVIRONMENTAL CONTROL ASPECTS OF IN SITU COAL GASIFICATION: GROUND WATER QUALITY CHANGES AND SUBSIDENCE EFFECTS

FY 1980 FUNDING LEVEL

Environmental and Safety Engineering Division (DOE/ASEV).....$300,000
Office of Research and Development (EPA/IERL-CI).....$120,000

ORGANIZATION AND CONTRACT NUMBER

Lawrence Livermore National Laboratory
P.O. Box 808
Livermore, CA 94550

Contract Number: W-7405-Eng-48

PRINCIPAL INVESTIGATOR

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OBJECTIVE(S)

Two important environmental concerns associated with in situ coal gasification (now generally called Underground Coal Gasification - UCG) are (1) the possibility of ground-water contamination by reaction products that remain underground after gasification and (2) ground subsidence. The intermediate objectives of this project include measurements and assessments of changes in ground-water quality and subsidence effects in the vicinity of UCG experiments, and the development of a predictive capability with regard to these effects that is applicable to commercial scale UCG. The ultimate objective is the identification of appropriate control technologies.

APPROACH

Our investigation of ground-water quality effects of UCG includes ground-water sampling and analysis before, during, and after three UCG experiments, laboratory studies of ash-leaching and of contaminant sorption by coal and other media, and computer modeling of the evolving plume of contaminated ground water.

The subsidence studies involve field investigations carried out in conjunction with UCG experiments, triaxial strength measurements of core samples, and the application and validation of a finite element computer code for subsidence prediction. The field investigations include both surface and subsurface ground deformation measurements.

PROGRESS AND RESULTS IN FISCAL YEAR 1980

The effects of UCG on ground-water quality continued to be investigated during the past year by means of a ground-water monitoring program and laboratory experiments. Water quality monitoring is now in progress at the sites of three UCG experiments conducted in northeastern Wyoming by the Lawrence Livermore National Laboratory (LLNL). Measurements near the first experiment (Hoe Creek I, 1976) showed that, in this instance, the largest group of organic contaminants consisted of phenolic materials. The phenols were concentrated in a shell-like layer just outside the burn boundary at an initial level of approximately 400 ppm. Our measurements show that in the first 25 months after gasification, the concentration of phenolic materials near the gasification cavity decreased by more than two orders of magnitude - probably as a result of sorption by the surrounding coal. However, this natural cleansing process may not be completely effective, as suggested by Fig. 1, which indicates that after nearly four years the concentration of the phenolic materials is still more than 200 ppb - roughly 100 times the baseline value.

The subsurface ground movement and potential surface subsidence associated with UCG are also of significant environmental concern - in part, because these phenomena can affect the dispersal of underground residual contaminants. We deployed extensive arrays of surface and subsurface geotechnical instruments at the sites of the Hoe Creek II and Hoe Creek III experiments to measure these effects. The instruments included borehole extensometers, deflectometers, electrical shear strips, electrical piezometers, and specially designed isolation bench marks. These instruments, together with hydraulic head measurements and post-burn coring operations, have provided a picture of the effects of cavity roof collapse at these two sites. Both experiments resulted in the interconnection of the Felix No. 2 Coal aquifer, the overlying Felix No. 1 Coal aquifer (which was also gasified), and an overlying channel sand aquifer. Extensive surface subsidence at the Hoe Creek III site began about three weeks after gasification and has been carefully followed by means of photographs and tape extensometer measurements of the displaced surface monuments.

The results of the continuing ground-water measurements in the vicinity of the Hoe Creek II experiment (completed in 1977) have been particularly interesting. We have monitored the ground water in more than a dozen wells and in all three aquifers of interest. Some water quality analyses are performed in the field, and preserved samples are sent for more detailed analysis to the U.S. Geological Survey Central Laboratory and to LLNL. Since the rubble-filled cavity represents an interconnection of three aquifers, the early-time deposition and subsequent dispersal of the contaminants, as well as the ground-water chemistry, is quite complex. These complexities appear to have an important bearing on the question of suitable control technologies.

Two interesting characteristics of the ground-water contaminants have become increasingly apparent during FY 81. Of particular importance is the observation that ground-water contaminants appear to persist for longer periods in the ground waters in and near the gasification cavity

than had been anticipated. An example of such persistence has been mentioned above (Fig. 1). The contaminant species plotted in Fig. 2 - ammonium, flouride, and boron - are examples of cavity contaminants that increased significantly after gasification and have persisted in the cavity ground water. Even in wells quite far from the cavity, some contaminants are persistent. The phenol concentration in a well about 200 ft from the cavity has remained at a level of five times the baseline value for more than two years.

A second observation of importance is that the concentrations of the contaminants deposited in the overlying Felix No. 1 Coal aquifer (20 to 30 ft above the Felix No. 2 at site II) are roughly two orders of magnitude greater than the contaminant concentrations measured in the Felix No. 2 Coal aquifer. Some interesting examples of phenol concentrations in the Felix No. 1 Coal are shown in Fig. 3. These observations of persistence and deposition geometry have led to new hypotheses concerning the mechanisms for contaminant formation and deposition, and have suggested new approaches to the development of control technologies.

The relative persistence of some of the ground-water contaminants have also helped to identify them as being of special environmental importance. In Table I, we have provided a tentative list of contaminants that increase as a result of UCG, have a tendency to persist, and may be of environmental concern. Note that organic bases are not included, since their concentration after 15 months is roughly 1000 times less than the acids and neutrals.

TABLE III. Ground-water Contaminants Resulting from UCG (at Hoe Creek) that may be of Environmental Significance.

Species	Maximum Concentrations 15 months after gasification
1. Inorganics	
Sulfide	57 ppm
Ammonium	26 ppm
Thiocyanate	20 ppm (2.5 yr)
Fluoride	9 ppm
Boron (Borates)	2 ppm
Cyanide	0.1 ppm
2. Organics	
Low molecular weight phenolic compounds (phenol, naphthol, and their derivatives)	41 ppm
Low molecular weight aromatic hydrocarbons (benzene, naphthalene, and their derivatives)	15 ppm

PLANS FOR FISCAL YEAR 1981

Activities during FY 81 will include the completion of several additional water-sampling wells at the Hoe Creek site. Their purpose is to follow the expanding zone of contamination, and to provide additional insight concerning the spatial distribution of the underground contamination that results from UCG. The post-burn coring program at site III will be completed and the data will be digitized and analyzed. Further analysis of the data provided by the subsurface geotechnical instruments used at Hoe Creek III will also take place.

We are planning to participate in the large coal block gasification experiments at the new DOE UCG site near Centralia, Washington. Large blocks of coal at a coal seam outcrop will be isolated, and short gasification experiments will be performed. Post-burn excavation will provide a direct view of early-time cavity formation. We hope to use these same experiments to obtain more definitive information concerning the formation and deposition of organic contaminants.

At extended intervals, we will continue to monitor ground-water quality and subsidence at the Hoe Creek site, for which a unique collection of chemical and hydrogeological data now exists.

REPORTS PUBLISHED, SIGNIFICANT PRESENTATIONS, AND OTHER CONTRIBUTIONS IN FISCAL YEAR 1980

1. H.C. Ganow, "Surface Subsidence Associated with the Third UCG Experiments at Hoe Creek," in LLL In Situ Coal Gasification Project, Quarterly Progress Report, Lawrence Livermore Laboratory, Livermore, CA, UCRL-50026-79-4 (1980).

2. F.T. Wang and S.W. Mead, "Water Quality Measurements at Hoe Creek No. 3," in LLL In Situ Coal Gasification Project, Quarterly Progress Report, Lawrence Livermore Laboratory, Livermore, CA, UCRL-50026-79-4 (1980).

3. E. Raber, R. Stone, and F. Wang, "Hydrologic Effects Resulting from Aquifer Interconnection at Hoe Creek No. 2 and No. 3," in LLL In Situ Coal Gasification Project, Quarterly Progress Report, Lawrence Livermore Laboratory, Livermore, CA, UCRL-50026-79-4 (1980).

4. F.T. Wang, S.W. Mead, and D.H. Stuermer, "Water Quality Measurements at Hoe Creek," in LLL In Situ Coal Gasification Project, Quarterly Progress Report, Lawrence Livermore Laboratory, Livermore, CA, UCRL-50026-80-1 (1980).

5. H.C. Ganow, "Postburn Coring Program at Hoe Creek No. 3," in LLNL Underground Coal Gasfication Project, Quarterly Progress Report, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50026-80-3 (1980).

6. S.W. Mead, F.T. Wang, D.H. Stuermer, E. Raber, H.C. Ganow, and R. Stone, Implications of Ground-water Measurements at the Hoe Creek UCG Site in Northeastern Wyoming, Lawrence Livermore Laboratory, Rept. UCRL-84083 (1980). This paper was prepared for submittal to the Sixth Annual Underground Coal Conversion Symposium, Afton, Oklahoma, July 13-17, 1980.

7. Warren Mead and Ellen Raber, Environmental Controls for Underground Coal Gasificaion: Ground-water Effects and Control Technologies, Lawrence Livermore Laboratory, Rept. UCRL-84075. This paper was prepared for submittal to the Second DOE Environmental Control Symposium, Reston, Virginia, March 17-19, 1980.

PROJECTED MILESTONES FOR FISCAL YEAR 1981 OR LATER

March 1982 - FY 81 Annual Report
March 1983 - FY 82 Annual Report

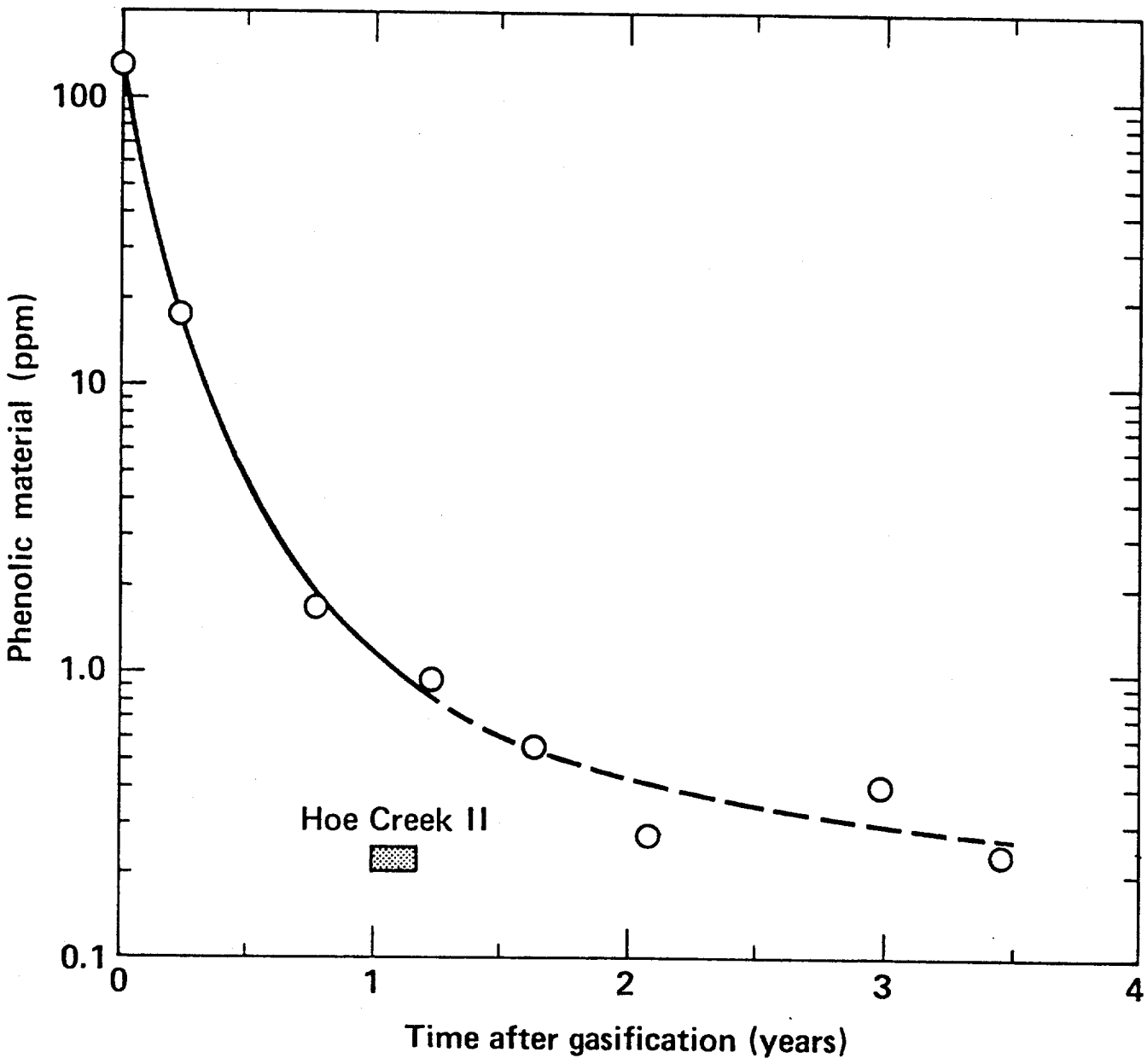

Figure 1. Decreasing phenol concentrations near the edge of the Hoe Creek I gasification cavity as a function of time. The data were obtained from a well located approximately 2 feet outside the gasification cavity. The occurrence of the Hoe Creek II experiment (less than 300 ft away) is also indicated.

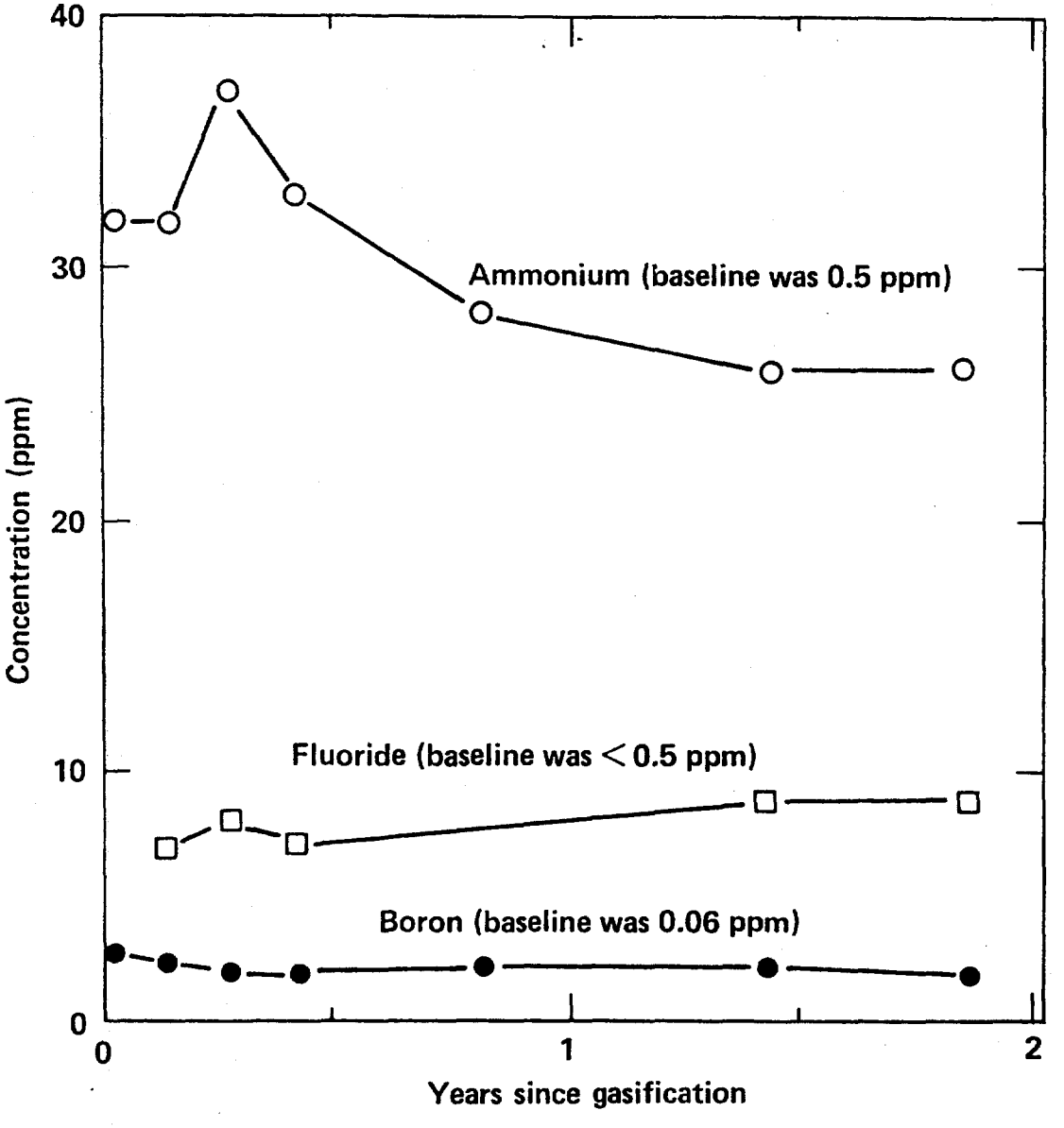

Figure 2. Concentrations of important contaminants inside the Hoe Creek II cavity as a function of time. Note that these contaminants have persisted with little change in concentration for nearly two years.

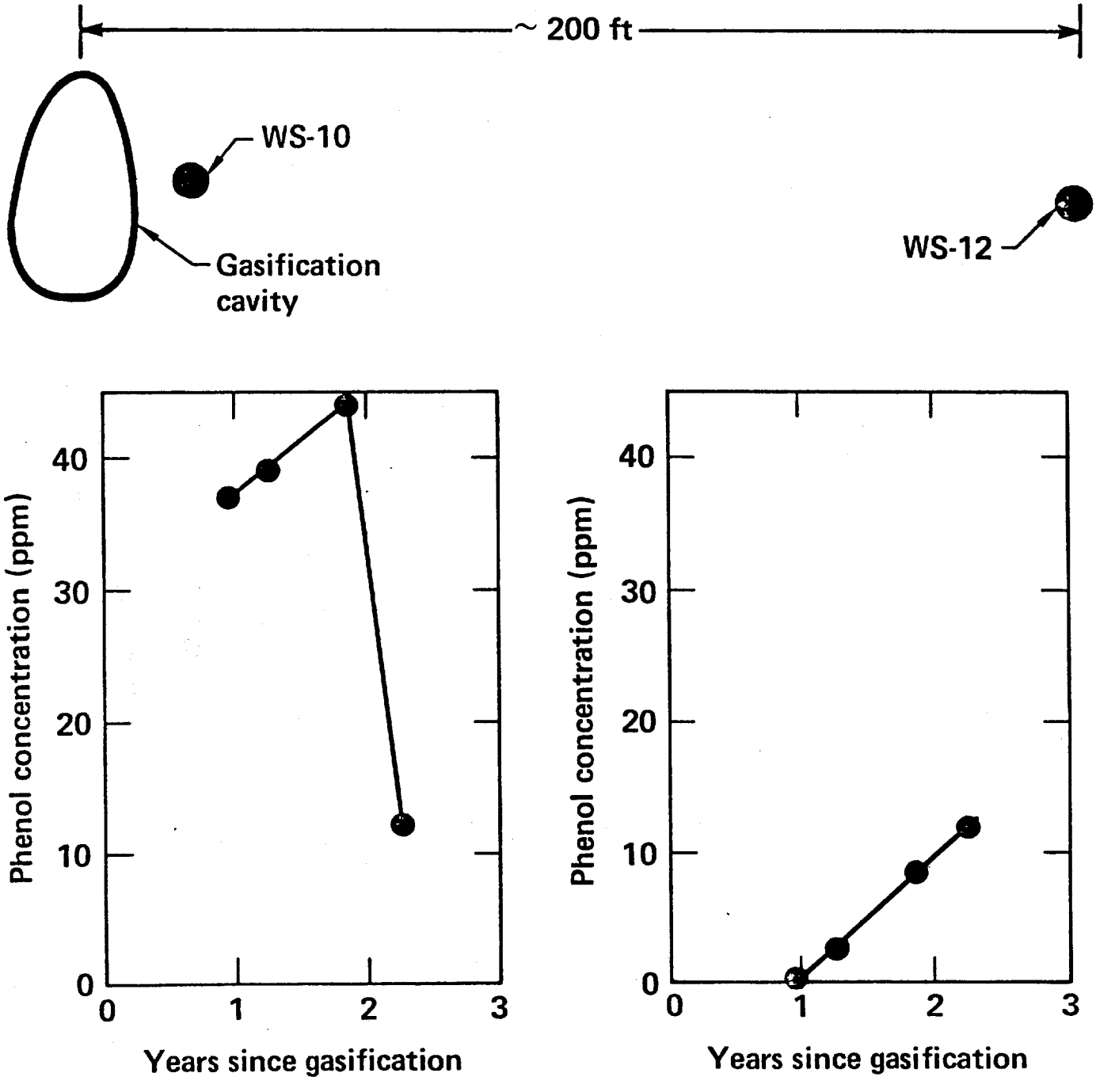

Figure 3. Changing phenol concentrations in the Felix No. 1 Coal aquifer as a function of time since the Hoe Creek II experiment.